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Authors: Liukkonen-Anttila, Tuija, Putaala, Ahti, and Hissa, Raimo

Source: Wildlife Biology, 5(3) : 147-156

Published By: Nordic Board for Wildlife Research

URL: https://doi.org/10.2981/wlb.1999.019

Does shifting from a commercial to a natural diet affect the nutritional status of hand-reared grey partridges *Perdix perdix*?

Tuija Liukkonen-Anttila, Ahti Putaala & Raimo Hissa

Liukkonen-Anttila, T., Putaala, A. & Hissa, R. 1999: Does shifting from a commercial to a natural diet affect the nutritional status of hand-reared grey partridges *Perdix perdix*? - Wildl. Biol. 5: 147-156.

Two feeding trials on hand-reared grey partridges *Perdix perdix* were performed to study the effect of a change from a commercial to a natural diet on body mass, food consumption, metabolised energy coefficient, gut morphology and some blood metabolites. We simulated the abrupt change in the diet which takes place when hand-reared birds are released into the wild. In the test group body mass decreased significantly after the change in diet. However, within one week body mass started to increase again, but it stabilised at a lower level than in control birds. Birds in the test group consumed more food (fresh weight) during the feeding trial and even produced more excreta during the second, fourth and fifth week of the feeding trial. Gross energy intake, amount of metabolised energy and metabolised energy coefficient decreased and excretory energy content increased during the feeding trial. No differences were seen in the analysed blood metabolites. Gizzards of the test birds were heavier than gizzards of the control birds. We conclude that the abrupt change from a commercial to a natural diet with the following difference in diet composition affects the partridge's ability to utilise nutrients from food available in the wild. According to our study, a period of six weeks may be inadequate for partridges to get totally adapted to a new diet.

Key words: blood metabolites, body mass, diet quality, grey partridge, metabolised energy coefficient, Perdix perdix

Tuija Liukkonen-Anttila, Ahti Putaala & Raimo Hissa, Department of Biology, University of Oulu, P.O.Box 3000, Oulu FIN-90401, Finland - e-mail: tuijala@mail.student.oulu.fi

Received 20 May 1998, accepted 19 April 1999

Associate Editor: Ralph J. Gutiérrez

Studies on several galliform species have shown that hand-reared birds differ in their physiology and morphology from their wild counterparts (Moss 1972, 1983, Majewska, Pielowski, Serwatka & Szott 1979, Hissa, Rintamäki, Virtanen, Lindén & Vihko 1990, Putaala & Hissa 1993, 1995). For example, captive gallinaceous birds fed commercial diets had shorter intestinal tracts and lighter gizzards than wild birds (Moss 1972, Hanssen 1979a,b, Majewska et al. 1979, Putaala & Hissa 1995). These physiological and morphological differences between hand-reared and wild birds may influence whether captive-reared and then released birds will be successful in the wild.

The first few weeks after release into the wild seem to be most critical for the survival of hand-reared grey partridges *Perdix perdix* (Panek 1988, Dowell 1990, Putaala, Turtola & Hissa in press). Although abnormal behaviour of hand-reared birds may render them prone to predation (Thomas 1987, Dowell 1990, Garson, Young & Kaul 1992), the limited abil-

ity of their digestive systems to use natural food may contribute to their poor survival. It is even possible that birds starve to death before their digestive system adapts to a new diet (Putaala & Hissa 1993). The adaptation from commercial to natural foods is assumed to take several weeks, if not months (Moss & Trenholm 1987, Moss 1989, Redig 1989).

Plant food contains cellulose, which makes it relatively indigestible and low in nutrient quality. When the digestibility of a diet decreases due to increasing amounts of indigestible components, birds may show an increased ability to digest the food (Moss & Trenholm 1987). Daily food consumption of commercial low-fibre diet is presumed to be lower than of natural high-fibre diet (Moss 1972, Miller 1975, Gasaway 1976). Northern bobwhite *Colinus virginianus* and scaled quail *Callipepla squamata* are able to increase their food consumption with low-energy diets to a level which is high enough to maintain body mass (Giuliano, Lutz & Patino 1996).

If hand-reared birds are subjected to an abrupt change in the diet, their poor ability to use new foods may be expressed as starvation. Starvation is known to affect many blood parameters. Lowered plasma glucose or protein levels can indicate malnutrition (Halliwell 1981, Lewandowski, Campbell & Harrison 1986). As a result of prolonged starvation the plasma uric acid level may increase (e.g. Jeffrey, Peakall, Miller & Herzberg 1985, Robin, Cherel, Girard, Géloen & Le Maho 1987). Finally, starvation decreases the plasma level of triiodothyronine (T_3) in hens *Gallus gallus* (Klandorf, Sharp & Macleod 1981) and herring gulls *Larus argentatus* (Jeffrey et al. 1985), and increases the level of thyroxine (T_4) in hens (Klandorf et al. 1981).

The aim of our study was to determine if the poor performance of hand-reared partridges after release into the wild could be explained by digestive constraints associated with changing diets. Considering previous studies of hand-rearing and the use of commercial poultry diets (Moss 1972, 1983, Majewska et al. 1979, Paganin & Meneguz 1992, Putaala & Hissa 1995) we assumed that the change in diet would result in lowered body mass, higher amount of consumed food, lowered metabolised energy coefficient, changes in some blood metabolites, and changes in gut morphology.

Material and methods

We conducted two feeding trials from January to April in 1996 and 1997. Changes in body mass were closely monitored in both years. In 1996, we investigated how a change in diet affected food consumption (fresh/dry weight), excreta production, and metabolised energy coefficient. In 1997 we studied the effect of a change in diet on some blood metabolites.

In 1996, we used a total of 30 seven-month-old female hand-reared grey partridges taken from four different broods. A detailed description of the rearing conditions was given in Putaala & Hissa (1995). Birds were maintained in large outdoor aviaries until six months old and offered pelleted commercial poultry diet (Täsmä-Herkku 2; Raisio, Finland). At the age of seven months birds were randomly sorted to either a test or control group with equal numbers of birds from each brood. Birds were housed individually in cages of 50 × 40 × 40 cm. Before starting the feeding experiments the birds were housed indoors for three weeks to get acclimated to the prevailing conditions. During the feeding trial birds in every other cage were fed a commercial diet (control) and the remainder were fed a natural diet (test).

In 1997, we investigated how the change in diet affected some blood parameters. We used a total of 24 seven-month-old hand-reared grey partridges (12 males and 12 females) from three different broods reared as described above. Both groups contained an equal number of both sexes. In this trial the preconditioning period was extended to nine weeks, to make sure that the birds were acclimated when the experiment started.

In both years the photoperiod of the room in which the birds were housed was 7 L/17 D (lights went on at 09:00 and simulated the natural light/dark cycle in mid-January in Central Finland). The room temperature was +15°C (±1°C).

Feeding of control and test birds

During the acclimation period all birds were fed a pelleted commercial diet (Täsmä-Herkku 2). Food, water, and grit were available *ad libitum*.

The weight of the food given to the birds and the food left over were recorded every day to the nearest 0.1 g. Before the feeding trial the energy content of different food items was determined using a Gallencamp bomb calorimeter (Cambridge Instrument Co Ltd, England) after samples were dried for two days at +60°C. Fibre, protein, and fat contents were

Table 1. Nutrient content of natural and commercial (Täsmä-Herkku 2) food items used in the feeding trials of grey partridge in 1996 and 1997.

Composition	Galeopsis sp., seed	Polygonum lapathifolium, seed	Fallopia convolvulus, seed	Oat, grains	Barley, sprouts	Täsmä-Herkku 2
Water content, %	2.7	1.2	2.5	4.9	90.0	6.3
Crude-fibre, %	18.9	18.9	19.8	14.0	23.5	5.3
Crude-protein, %	22.6	9.8	13.1	13.4	31.6	14.5
Crude-fat, %	37.3	4.2	-	4.2	2.4	6.5
Energy, kJ/g	258.6	186.5	155.0	171.5	186.3	157.4

analysed by Soil Analysis Service (Mikkeli, Finland). More detailed information about the food items is given in Tables 1 and 2.

After the acclimation period, the test group was only fed food commonly found in the natural diet of grey partridge during winter in Finland (Pulliainen 1965, 1984): sprouts (in this case barley *Hordeum vulgare*), oat *Avena sativa* grains and weed seeds (*Galeopsis* sp., *Fallopia convolvulus*, *Polygonum lapathifolium*). The control group continued to receive only pelleted commercial food. Food was offered to the birds in feeding containers which were divided into four sections, one for each food item and one for grit. Food added and food left was weighed (fresh/dry weight) daily for every food item separately. Thus, the food, and its energy content (dry weight), eaten by each bird was exactly recorded.

Sprouts (30 g) were changed and weighed every day. To examine the evaporation rate of the sprouts, 3 × 30 g sprouts were added to feeding dishes in empty cages. Samples were weighed every day and the water loss was determined on a dry matter basis. Therefore, we were able to estimate the sprouts' daily weight loss due to evaporation and consumption.

Table 2. Ingredients of pelleted commercial poultry food (Täsmä-Herkku 2) produced by Raisio, Finland.

Ingredient	Content
Barley	26.0 %
Oat	15.0 %
Wheat, bran	10.0 %
Soya, crushed	10.0 %
Calciumcarbonate	9.7 %
Wheatprotein	4.0 %
Animal fat	3.0 %
Wheatsyrup	2.0 %
Fishpowder	1.7 %
Greenpowder	1.0 %
Vegetable oil	0.9 %
Methionine	0.33 %
Lysine	0.7 %
Ca	3.9 %
P	0.52 %
Vitamin-A	12,000 IU/kg
Vitamin-D_3	2,500 IU/kg
Vitamin-E	35 mg/kg
Cu	20 mg/kg
Se	2 mg/kg

Excreta, metabolised energy and metabolised energy coefficient

Every third day the birds were weighed to the nearest gram in the morning before the lights went on and before the birds had fed. Excreta were collected once a week. Because the energy content of the excreta originating from the intestine differs from that of the caecum, all the excreta were mixed together before drying and pelleting (Thompson & Boag 1975). Before homogenisation with a mortar, excreta were dried at +60°C for two days. The energy content of three pellets (ca 1.0 g each) per excreta sample was estimated in the same way as the food samples.

Metabolised energy (ME) content for one day was determined as the difference between gross energy (GE) intake and excretory energy (EE). The metabolised energy coefficient (MEC) was calculated as ME/GE. Gross energy intake was estimated from the consumed food mass (M) and its gross energy content (CDc); GE = M × CDc. Excreted energy content was calculated using the mass of the excreta (m) and the mean energy content of three 1-g excreta pellets (CDe) (for the terminology and formulae see Kendeigh, Dol´nik & Gavrilov 1977, Nikiforov 1992).

Blood sampling and analytical methods

Blood samples of 1.5 ml were collected in 1997 from all birds between 10:00 and 14:00. Blood samples were collected three, five, seven, and nine weeks after the birds had been brought indoors to ensure that they were acclimated to indoor conditions when the blood sampling started. During the feeding trial, samples were collected one, two, four, and six weeks after the change in diet.

Food containers were removed before dark the day before sampling so that the birds would not be able to

eat just before blood samples were taken. Blood was collected from the *vena brachialis* using needles (size 23 G) and syringes with 20.8% EDTA (pH 7.4) as an anticoagulant. Samples were centrifuged to separate the plasma.

Haemoglobin (Hb) and haematocrit (Hcr) were analysed from whole blood whereas glucose, uric acid, triglycerides, total protein, T_3 and T_4 were analysed from plasma. Hb and Hcr were analysed from samples drained directly into capillary tubes. Hb was analysed with an Ames Hb Mini-Pak (Oy Algol Ab, Espoo, Finland) in an Ames Minilab PC. Hcr was determined using a Micro-Haematocrit Reader.

Glucose was analysed using the Boehringer MPR 2 Glucose /GOD-Perid Method, uric acid using Boehringer MPR 2 Test-Combination Uric Acid PAP, total protein using Boehringer MPR 3 total protein, and triglycerides using Boehringer Peridochrom® Triglycerides GPO-PAP (Oriola, Helsinki, Finland). T_3 and T_4 were analysed using the Orion Diagnostica SPECTRIA (radioimmunoassay) coated tube T_3 and T_4 test procedures (Farmos Diagnostica, Turku, Finland).

Morphological features

After finishing the feeding trial in 1997 five males from both diet groups were killed. The gizzards were emptied and the inner cuticle was removed before weighing. Livers were weighed separately. Before measuring, both the caecum and the small intestine were straightened but not stretched and mesenteries were removed.

Statistical analysis

All statistical analyses were performed using the statistical software package SPSS 6.3.1. As there was no difference in the response to the change in diet between sexes (F_1 = 1.938, P = 0.178) the data from females and males were pooled in 1997.

Body mass, changes in body mass (Δm), food intake (fresh/dry weight), excreta production, GE, EE, ME and MEC in test and control birds at the end of the acclimation period were tested using t-test and during the feeding trial using repeated measures analysis of variance (ANOVAR). When assumptions for ANOVAR were not met, i.e. if Mauchly's criterion was significant, we used significance levels adjusted according to the Huynh-Feldt epsilon criterion (Potvin, Lechowicz & Tardif 1990).

We tested Hb, Hcr, glucose, triglycerides, total protein, uric acid, T_3 and T_4 in test and control birds at the end of the acclimation period using t-test. Blood parameters from the feeding trial period were first $\log_{10}$-transformed and then tested using ANOVAR.

The weights of the gizzards and livers and the

Table 3. Body mass (weight) of grey partridges in week 0-6 in 1996 and 1997. Week 0 includes data obtained before the diet was changed; week 0.5-6 include data obtained during the feeding trial, i.e. after the change in diet.

Week	Group	Weight in 1996	Weight in 1997
0	Test	337.3 ± 5.8[1]	363.3 ± 5.0
	Control	346.5 ± 5.8	368.8 ± 4.9
		t_{28} = -1.125[2]	t_{22} = -0.771
		P = 0.270	P = 0.449
0.5	Test	325.5 ± 5.5	352.5 ± 5.0
	Control	348.9 ± 5.6	368.9 ± 4.9
1	Test	315.4 ± 6.0	345.3 ± 4.9
	Control	353.1 ± 5.4	363.7 ± 4.6
2	Test	320.7 ± 7.2	345.0 ± 5.2
	Control	351.3 ± 4.7	364.8 ± 4.9
3	Test	329.0 ± 7.4	350.9 ± 5.7
	Control	364.9 ± 5.2	368.8 ± 5.3
4	Test	330.2 ± 6.8	358.5 ± 5.8
	Control	361.9 ± 5.0	372.1 ± 4.9
5	Test	336.0 ± 6.8	355.2 ± 5.1
	Control	367.2 ± 5.7	369.3 ± 5.3
6	Test	334.1 ± 7.1	358.3 ± 4.8
	Control	364.1 ± 5.6	372.1 ± 4.6
		F_1 = 13.753[3]	F_1 = 4.909
		P = 0.001	P = 0.038

[1] g, mean ± SE;
[2] test statistics of t-test, N = 30 in 1996 and N = 24 in 1997;
[3] test statistics of ANOVAR.

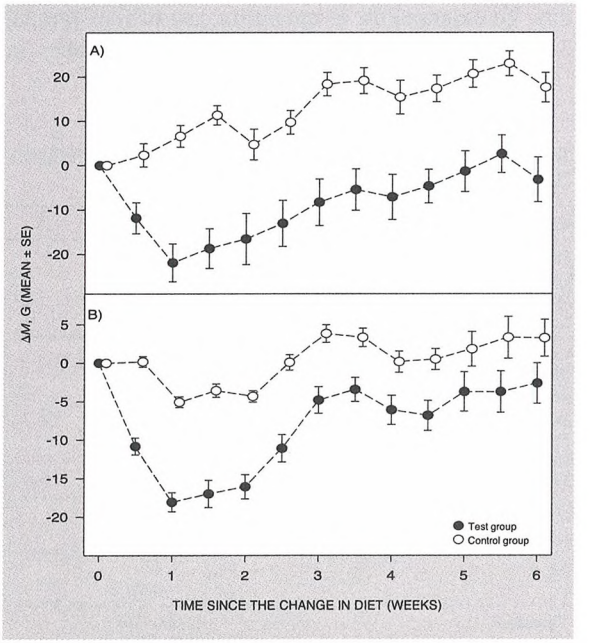

Figure 1. Change in body mass (Δm ± SE) of grey partridge after a change from a commercial to a natural diet in 1996 (A; N = 15 in each group) and 1997 (B; N = 12 in each group).

Table 4. Natural food consumed by grey partridges during the feeding trial in 1996; N = 15 in each group. For definition of week 1-6 see legend of Table 3.

Week	Barley sprouts, fresh, g ± SE	Barley sprouts, dry, g ± SE	Oat grains, g ± SE	Weed seeds, g ± SE
1	7.3 ± 0.9	0.72 ± 0.1	3.0 ± 0.3	6.8 ± 0.9
2	16.2 ± 1.7	1.62 ± 0.2	6.1 ± 0.8	10.4 ± 1.4
3	9.1 ± 1.3	0.91 ± 0.1	4.9 ± 0.8	7.2 ± 0.7
4	9.2 ± 1.6	0.92 ± 0.2	7.7 ± 0.8	8.8 ± 0.7
5	11.6 ± 1.3	1.16 ± 0.1	7.8 ± 0.9	6.5 ± 0.8
6	21.1 ± 1.5	2.11 ± 0.2	8.0 ± 0.9	6.1 ± 0.6

lengths of the small intestines and caeca in test and control birds were compared using Mann-Whitney U-test.

Results

Body mass

In 1996, at the end of the acclimation period, no differences in body mass were seen between the two groups (Table 3). During the feeding trial body masses of the test group birds were lower than for the control group birds (see Table 3, Fig. 1).

In 1997, there was no difference in body mass between the groups at the end of the acclimation period (see Table 3). After the change in diet, the birds in the test group were lighter than the birds in the control group (see Table 3 and Fig. 1). However, they started to gain body mass within a week. During the fourth week the body mass of the birds in both groups dropped, but not as low as after the change of diet.

Amounts of consumed food, produced excreta and metabolised energy coefficient

No difference was recorded in the mass of food consumed at the end of the acclimation period (see Table 5). During the first week after the change in diet, birds in the test group were suspicious about the new food and ate less than birds in the control group (see Table 4 for preferences). Food consumption based on fresh weight increased in the test group compared to the control group in the second week and was somewhat higher during the whole feeding trial (Table 5). On the basis of the dry weight of food, the test group consumed less food than the control group (see Table 5). This was due to the high water content of the sprouts.

At the end of the acclimation period no difference

Table 5. Amount of consumed food (fresh/dry) and produced excreta, gross energy (GE) intake, excretory energy (EE) and metabolised energy (ME) content and metabolised energy coefficient (MEC) of grey partridges during the feeding trials in 1996. N = 15 in each group. For definition of week 0-6 see legend of Table 3.

Week	Group	Fresh food, g/day	Dry food, g/day	GE, kJ/day	Excreta (dry), g/day	EE, kJ/day	ME, kJ/day	MEC
0	Test	24.4 ± 1.9[1]	22.0 ± 0.8	383.7 ± 13.7	9.1 ± 0.3	105.5 ± 3.7	278.2 ± 11.7	0.72 ± 0.01
	Control	22.9 ± 1.5	22.4 ± 1.4	360.3 ± 16.7	8.8 ± 0.5	103.6 ± 6.7	256.7 ± 13.0	0.71 ± 0.01
		t_{28} = -0.29[2]	t_{28} = -0.29	t_{28} =1.08	t_{28} = 0.55	t_{28} = 0.25	t_{28} = 1.23	t_{28} = 0.73
		P = 0.771	P =0.771	P = 0.289	P = 0.584	P = 0.804	P = 0.231	P =0.473
1	Test	17.1 ± 1.1	10.55 ± 0.8	219.1 ± 18.9	6.0 ± 0.4	75.3 ± 6.1	143.9 ± 16.9	0.62 ± 0.04
	Control	22.3 ± 0.4	20.10 ± 0.3	350.9 ± 5.5	10.4 ± 0.3	121.3 ± 4.2	229.7 ± 5.9	0.65 ± 0.01
2	Test	32.8 ± 2.6	18.22 ± 1.4	371.2 ± 30.1	13.2 ± 1.0	157.4 ± 11.2	213.9 ± 25.1	0.56 ± 0.03
	Control	24.8 ± 0.9	22.34 ± 0.8	389.9 ± 14.0	4.1 ± 0.1	45.6 ± 1.4	344.4 ± 14.0	0.88 ± 0.01
3	Test	21.2 ± 1.5	13.05 ± 0.8	264.9 ± 16.6	9.1 ± 0.6	99.8 ± 7.4	165.1 ± 14.9	0.61 ± 0.03
	Control	18.6 ± 0.6	16.72 ± 0.5	291.9 ± 9.3	10.7 ± 0.3	97.3 ± 4.4	194.6 ± 9.2	0.66 ± 0.02
4	Test	25.7 ± 1.7	17.43 ± 0.6	332.7 ± 10.9	11.6 ± 0.7	123.5 ± 7.9	209.2 ± 13.1	0.62 ± 0.03
	Control	22.6 ± 0.6	20.29 ± 0.6	354.2 ± 10.1	8.0 ± 0.3	74.2 ± 3.0	280.0 ± 9.3	0.79 ± 0.01
5	Test	26.2 ± 1.5	15.70 ± 0.6	306.6 ± 11.2	11.9 ± 0.6	154.1 ± 7.9	152.5 ± 11.8	0.49 ± 0.03
	Control	23.4 ± 0.7	21.06 ± 0.7	367.7 ± 11.7	7.2 ± 0.2	86.6 ± 4.5	281.1 ± 9.2	0.77 ± 0.01
6	Test	37.2 ± 1.2	15.39 ± 0.9	294.7 ± 15.7	9.0 ± 0.9	95.3 ± 5.7	199.4 ± 16.4	0.67 ± 0.03
	Control	18.7 ± 0.7	16.85 ± 0.6	294.1 ± 11.1	8.2 ± 0.3	76.4 ± 3.1	217.7 ± 8.9	0.74 ± 0.01
		F_1 = 16.130[3]	F_1 = 30.898	F_1 = 8.611	F_1 = 18.148	F_1 = 9.752	F_1 = 58.807	F_1 = 15.230
		P = 0.001	P < 0.001	P = 0.007	P < 0.001	P = 0.004	P < 0.001	P < 0.001

[1] mean ± SE;
[2] test statistics of t-test;
[3] test statistics of ANOVAR.

Table 6. Blood parameters analysed during the feeding trial in 1997. N = 12 in each group. For definition of week 0-6 see legend of Table 3.

Week	Group	Haemoglobin, g/dl	Haematocrit, %	Glucose, mmol/l	Uric acid, µmol/l	Total protein, g/100 ml	Triglyserides, mmol/l	T_3, nmol/l	T_4, nmol/l
0	Test	13.2 ± 0.2[1]	43.4 ± 0.6	8.78 ± 0.23	190.01 ± 13.34	3.22 ± 0.10	0.33 ± 0.03	0.70 ± 0.08	13.56 ± 0.90
	Control	13.4 ± 0.3	44.8 ± 0.9	8.23 ± 0.23	164.28 ± 19.12	3.26 ± 0.12	0.31 ± 0.03	0.75 ± 0.11	14.99 ± 1.82
		t_{22} = -0.50[2]	t_{22} = -1.33	t_{22} = 1.66	t_{22} = 0.39	t_{22} = 0.25	t_{22} = 1.10	t_{22} = -0.37	t_{22} = -0.71
		P = 0.619	P = 0.198	P = 0.111	P = 0.698	P = 0.803	P = 0.282	P = 0.712	P = 0.487
1	Test	13.1 ± 0.2	44.3 ± 0.9	9.08 ± 0.42	154.24 ± 21.40	3.30 ± 0.08	0.32 ± 0.02	0.80 ± 0.07	15.28 ± 0.36
	Control	13.4 ± 0.2	43.3 ± 0.7	8.98 ± 0.52	192.77 ± 36.27	3.33 ± 0.12	0.30 ± 0.02	0.74 ± 0.06	15.41 ± 0.59
2	Test	12.9 ± 0.4	41.9 ± 0.6	8.22 ± 0.39	155.49 ± 13.37	3.19 ± 0.14	0.26 ± 0.02	0.81 ± 0.10	17.38 ± 0.54
	Control	13.5 ± 0.3	43.5 ± 0.6	8.41 ± 0.40	191.26 ± 22.88	3.49 ± 0.08	0.30 ± 0.03	0.94 ± 0.20	17.03 ± 0.49
4	Test	13.7 ± 0.4	44.3 ± 0.9	9.34 ± 0.50	139.24 ± 20.06	3.49 ± 0.13	0.34 ± 0.03	0.96 ± 0.10	14.26 ± 0.58
	Control	13.9 ± 0.2	43.8 ± 0.8	8.65 ± 0.36	164.53 ± 11.83	3.34 ± 0.10	0.37 ± 0.05	0.86 ± 0.06	14.56 ± 0.31
6	Test	14.9 ± 0.5	46.7 ± 0.6	8.26 ± 0.30	147.18 ± 9.74	3.16 ± 0.14	0.41 ± 0.04	0.78 ± 0.09	14.52 ± 0.70
	Control	14.2 ± 0.2	46.3 ± 0.7	8.16 ± 0.38	227.66 ± 29.01	3.18 ± 0.13	0.38 ± 0.04	0.81 ± 0.09	14.67 ± 0.78
		F_1= 0.014[3]	F_1 = 0.077	F_1 = 0.527	F_1 = 1.593	F_1 = 0.033	F_1 = 0.035	F_1 = 0.015	F_1 = 0.022
		P = 0.908	P = 0.784	P = 0.476	P = 0.221	P = 0.858	P = 0.853	P = 0.905	P = 0.883

[1] mean ± SE;
[2] test statistics of t-test;
[3] test statistics of ANOVAR.

was seen between the diet groups in the dry mass of excreta, but after the change in diet the groups differed significantly from each other (see Table 5). Test birds produced more excreta in the second, fourth, and fifth week, whereas birds in the control group produced more excreta in the first and third week (see Table 5).

No differences between diet groups were seen in the GE, EE, ME, or MEC (see Table 5) at the end of the acclimation period. However, the change in diet lowered the GE, ME, and MEC, and increased the EE (see Table 5), in the test group compared with the control group.

Blood analysis

There was no difference between the groups in the haemoglobin and haematocrit values at the end of the acclimation period or during the feeding trial (Table 6). No difference was detected in plasma metabolites between the diet groups before or after the change in diet (see Table 6).

Morphological features

The only difference in morphological features between the groups was found for gizzard mass (Table 7). Birds fed natural food had heavier gizzards than birds fed pelleted commercial food. No difference between groups was observed in liver mass, total length of the caecum, or length of the small intestine.

Discussion

We examined the effects of an abrupt change from a commercial to a natural diet on some physiological and morphological parameters in the grey partridge. Changes in body mass, food consumption, metabolised energy coefficient, and some blood metabolites were monitored. Birds given natural food lost mass dramatically immediately after the change in diet but started to regain mass again within 7-10 days. They also consumed more food on fresh weight basis, produced more excreta, and had lower metabolised energy coefficients than birds in the control group which were fed a commercial diet during weeks 2-6. No differences were seen in analysed blood metabolites.

Table 7. Morphological responses of male grey partridges to a change from a commercial to a natural diet. N = 5 in each group.

Group	Gizzard, g	Liver, g	Small intestine, cm	Caeca, total length, cm
Test	6.03 ± 0.21[1]	3.65 ± 0.17	42.6 ± 1.7	19.1 ± 1.2
Control	4.67 ± 0.26	3.72 ± 0.18	40.8 ± 0.9	19.1 ± 0.8
	z = -2.4023[2]	z = -0.5222	z = -0.6325	z = -0.7425
	P = 0.0163	P = 0.6015	P = 0.5271	P = 0.4578

[1] mean ± SE;
[2] test statistics of Mann-Whitney U-test.

Gizzards of test birds were heavier than those of the birds in the control group.

Body mass, food consumption, and excreta

Although body mass alone is not a sufficient indicator of a bird's condition (van der Meer & Piersma 1994), it is one of the most important and useful tools for evaluating changes in a bird's nutritional status (Brittas & Marcström 1982, Barton & Houston 1993). Although the birds in the test group lost mass dramatically during the first week after the change in diet, they started to gain mass again in the second week. The decreases in body mass later on during the feeding trial were probably associated with hormonal effects due to the forthcoming breeding season. Unfortunately, we have no hormonal data to support this assumption. It is possible that the birds were still growing and their body mass was lower during the feeding trial, because the birds did not get enough energy for growth from the natural food.

Within one week after the change in diet the excreta of the test birds was soft, watery and grass-smelling, while excreta of the control group remained dry, hard and compact. Because the caecum plays an important role in the digestion of galliform birds (Suomalainen & Arhimo 1945, Fenna & Boag 1974, Thompson & Boag 1975, Moss 1983, 1989) and absorption of alimentary water (Gasaway, White & Holleman 1976), wet droppings may indicate reduced absorption of water from the caecal content. It is noteworthy, that the excreta of test birds reverted to a dry, hard form again at about the same time as the birds regained body mass. Barley fibre strands were visible in the excreta.

Birds in the test group consumed somewhat more food (fresh weight) and produced more excreta than the birds in the control group, a pattern which is similar to that of other species using fibre-rich natural foods (Moss 1972, Miller 1975, Gasaway 1976). Savory & Gentle (1976a) found increased food intake when dietary fibre increased and a larger gut size in Japanese quails *Coturnix coturnix japonica*. Quails adjusted their food intake in 8-10 days when their diets were changed (Savory & Gentle 1976b).

Birds in the control group ate more during the second week than during the first week and at the same time produced less excreta, which makes their MEC high. In the test group the birds consumed (on the fresh weight basis) more food during the sixth than during the fifth week. The ME is calculated on a dry food basis, and was lower during the fifth than sixth week. The difference between food consumption during these two weeks depends on the birds' choice of sprouts. This may refer to the forthcoming breeding season, when sprouts are very important to female galliform birds (Siivonen 1957).

Metabolised energy coefficient

The metabolised energy coefficient (MEC) varies with diet in galliform birds between 0.30 and 0.86 (for review, see Castro, Stoyan & Myers 1989). The MEC of our penned grey partridges ranged from 0.49 to 0.67 in the test group and from 0.61 to 0.88 in the control group. Nikiforov (1992) found that at -5°C the MEC of captive grey partridges ranged from 0.66 to 0.67 and their ME was about 279 kJ/day. In our study captive partridges were housed at +15°C, at which temperature their energy requirements are about 1.5 times lower than at -5°C (Hohtola, Hissa, Imppola, Pönni & Saarela 1991). The mean ME was lower in our test group but higher in our control group than the mean ME reported by Nikiforov (1992).

In some previous studies, the amount of fibre in the diet has not been documented to affect the daily gross energy intake in rock ptarmigan *Lagopus mutus* (Gasaway 1976) or the metabolisable energy in red grouse *Lagopus lagopus scoticus* (Moss & Trenholm 1987) and in Japanese quail (Starck & Kloss 1995). Nevertheless, according to Savory & Gentle (1979a) a fibre-rich diet affects the digestibility and metabolisable energy of the diet in Japanese quail. In general, for galliform birds eating fibrous plant food, the metabolised energy coefficient was lower than in most food types (Castro et al. 1989). Duke, Eccleston, Kirkwood, Louis & Bedbury (1984) found that preconditioning turkeys *Meleagris gallopavo* with high-fibre diet resulted in at least a fourfold increase in utilisation of cellulose. In our study, both the GE and ME of grey partridges decreased when their diets were changed from a commercial to a natural diet. This may also be attributable to higher levels of plant secondary compounds in a natural diet (Servello & Kirkpatrick 1987).

Morphological features

Increasing fibre levels in the diet increase the length of the intestine and the mass of the gizzard in the rock partridge *Alectoris graeca*, California quail *Lophortyx californicus*, red grouse, spruce grouse *Canachites canadensis*, and Japanese quail (Moss 1972, 1989, Fenna & Boag 1974, Savory & Gentle 1976a,

Moss & Trenholm 1987, Paganin & Meneguz 1992, Starck & Kloss 1995, but see Remington 1989). A sample of five males in each group may not have been adequate to make any generalisations on the effect of a diet change on the gut morphology of the partridges, but it may suggest a trend. As a response to the change from a commercial to a natural diet weights of gizzards increased. This probably indicated greater need for effective grinding ability. However, both groups had shorter guts, smaller gizzards and livers than wild partridges (Putaala & Hissa 1995) or partridges which originated from a wild stock and of which only 1-2 generations had been reared in captivity (Putaala & Hissa 1995). Moss (1972) showed that the caecal length of captive red grouse decreased from generation to generation.

The adaptation of digestive organs to changing diets takes at least two weeks in quails (Starck & Kloss 1995) and probably 4-6 weeks in red grouse (Moss & Trenholm 1987). According to Fenna & Boag (1974) adjustment takes about eight weeks while Duke et al. (1984) state that it takes 10 weeks. The gut dimensions of Japanese quail changed in three to four weeks when the diets were changed (Savory & Gentle 1976b). We did not find any differences between the groups in the lengths of small intestines or caeca, which probably means, that our six-week feeding trial was not sufficient to cause any noticeable differences in them.

Plasma analysis

We analysed some blood metabolites to study if the abrupt change in diet caused any starvation effects on test group birds. Since there were no differences in these parameters between the groups, this indicates either that the birds were not nutritionally stressed by the change in diet, or that the analysed metabolites were not sensitive to nutritional changes in birds. It must be emphasised that the birds in our study had food *ad libitum*, and the changed nutrition, therefore, probably did not cause starvation because the birds were able to increase their food intake.

Conclusions

The abrupt change in the diet from pelleted commercial to natural food items caused a sudden decrease in the body mass, food consumption (fresh weight), excreta production, gross energy intake, amount of metabolised energy and metabolised energy coefficient in the test group during the first week of the feeding trial. These changes probably were related to the birds' suspiciousness of new food items on the first day, and on the lower ability to digest natural food. Decreased body mass, gross energy intake, amount of metabolised energy and metabolised energy coefficient, and increased food consumption, produced excreta and amount of excretory energy during the feeding trial may also be attributable to the difference in diet composition. Therefore, we conclude that the change in diet and the new diet composition affected the nutritional status of the grey partridge. A six-week period of natural feeding in captivity before release may not be sufficient to make birds preconditioned to feeding in the wild.

Acknowledgements - this work was supported by a grant from the Finnish Ministry of Agriculture and Forestry and the Finnish Academy. We thank the staff of the Zoological Garden of Oulu University for their assistance during our study. We express our gratitude to Marja-Liisa Martimo for her work with the laboratory assays. Dr. Gutiérrez and two anonymous reviewers made valuable comments on the manuscript. This work has been reviewed and accepted by the Committee of Animal Experimentation of the University of Oulu (1/96).

References

Barton, N.W.H & Houston, D.C. 1993: A comparison of digestive efficiency in birds of prey. - Ibis 135: 363-371.

Brittas, R. & Marcström, V. 1982: Studies in Willow Grouse Lagopus lagopus of some possible measures of condition in birds. - Ornis Fennica 59: 157-169.

Castro, G., Stoyan, N. & Myers, J.P. 1989: Assimilation efficiency in birds: a function of taxon or food type? Mini review. - Comparative Biochemistry and Physiology 92A: 271-278.

Dowell, S.D. 1990: Differential behaviour and survival of hand-reared and wild grey partridge in the United Kingdom. - In: Church, K.E., Warner, R.E. & Brady, S.J. (Eds); Perdix V: Grey partridge and ring-necked pheasant workshop. Kansas Department of Wildlife and Parks, Emporia, pp. 230-241.

Duke, G.E., Eccleston, E., Kirkwood, S., Louis, C.F. & Bedbury, H.P. 1984: Cellulose digestion by domestic turkeys fed low or high fibre diets. - Journal of Nutrition 114: 95-102.

Fenna, L. & Boag, D.A. 1974: Adaptive significance of the caeca in Japanese quail and spruce grouse (Galliformes). - Canadian Journal of Zoology 52: 1577-1584.

Garson, P.J., Young, L. & Kaul, R. 1992: Ecology and conservation of the cheer pheasant Catreus wallichii: Studies in the wild and the progress of a reintroduction project. - Biological Conservation 59: 25-35.

Gasaway, W.C. 1976: Cellulose digestion and metabolism

by captive rock ptarmigan. - Comparative Biochemistry and Physiology 54A: 179-182.

Gasaway, W.C., White, R.G. & Holleman, D.F. 1976: Digestion of dry matter and absorption of water in the intestine and cecum of rock ptarmigan. - Condor 78: 77-84.

Giuliano, W.M., Lutz, R.S. & Patino, R. 1996: Reproductive responses of adult female northern bobwhite and scaled quail to nutritional stress. - Journal of Wildlife Management 60: 302-309.

Halliwell, W.H. 1981: Serum chemistry profiles in the health and disease of birds of prey. - In: Cooper, J.E. & Greenwood, A.G. (Eds); Recent advances in the study of raptor diseases. Proceedings of the International Symposium on Diseases of Birds of Prey, London, pp. 111-112.

Hanssen, I. 1979a: Micromorphological studies on the small intestine and caeca in wild and captive willow grouse (Lagopus lagopus lagopus). - Acta Veterinaria Scandinavica 20: 351-364.

Hanssen, I. 1979b: A comparison of microbiological conditions in the small intestine and caeca of wild and captive willow grouse (Lagopus lagopus lagopus). - Acta Veterinaria Scandinavica 20: 365-371.

Hissa, R., Rintamäki, H., Virtanen, P., Lindén, H. & Vihko, V. 1990: Energy reserves of the Capercaillie (Tetrao urogallus) in Finland. - Comparative Biochemistry and Physiology 97A: 345-351.

Hohtola, E., Hissa, R., Imppola, R., Pönni, J. & Saarela, S. 1991: Fasaanin ja peltopyyn lämpötalous (In Finnish with English summary: Cold thermogenesis in the summer and winter-acclimatized pheasants and partridges). - Suomen Riista 37: 18-26.

Jeffrey, D.A., Peakall, D.B., Miller, D.S. & Herzberg, G.R. 1985: Blood chemistry changes in food-deprived herring gulls. - Comparative Biochemistry and Physiology 81A: 911-913.

Kendeigh, S.C., Dol´nik, V.R. & Gavrilov, V.M. 1977: Avian energetics. - In: Pinowski, J. & Kendeigh, S.C. (Eds); Granivorous birds in ecosystems. Cambridge University Press, Cambridge, pp. 127-204.

Klandorf, H., Sharp, P.J. & Macleod, M.G. 1981: The relationship between heat production and concentrations of plasma thyroid hormones in the domestic hen. - General and Comparative Endocrinology 45: 513-520.

Lewandowski, A.H., Campbell, T.W. & Harrison, G.J. 1986: Clinical chemistries. - In: Harrison G.J. & Harrison, L.R. (Eds); Clinical avian medicine and surgery: including aviculture. W.B. Saunders, Philadelphia, pp. 192-200.

Majewska, B., Pielowski, Z., Serwatka, S. & Szott, M. 1979: Genetische und adaptive Eigenschaften des Zuchtmaterials zum Aussetzen von Fasanen. - Zeitschrift für Jagdwissenschaft 25: 212-226. (In German).

Miller, M.R. 1975: Gut morphology of mallards in relation to diet quality. - Journal of Wildlife Management 39: 168-173.

Moss, R. 1972: Effects of captivity on gut lengths in red grouse. - Journal of Wildlife Management 36: 99-104.

Moss, R. 1983: Gut size, body weight, and digestion of winter foods by grouse and ptarmigan. - Condor 85: 185-193.

Moss, R. 1989: Gut size and digestion of fibrous diets by tetraonid birds. - Journal of Experimental Zoology, Supplement 3: 61-65.

Moss, R. & Trenholm, I.B. 1987: Food intake, digestibility and gut size in red grouse. - British Poultry Science 28: 81-89.

Nikiforov, M.E. 1992: Bioenergetics of Grey partridge (Perdix perdix) in winter. - Gibier Faune Sauvage 9: 693-707.

Paganin, M. & Meneguz, P.G. 1992: Gut length of wild and reared rock partridges (Alectoris graeca): its role in release success. - Gibier Faune Sauvage 9: 709-715.

Panek, M. 1988: Study on introduction of aviary-reared partridges. - In: Polish Hunting Association (Ed.); Proceedings of Common Partridge (Perdix perdix) International Symposium, Poland 1985, pp. 217-224.

Potvin, C., Lechowicz, M.J. & Tardif, S. 1990: The statistical analysis of ecophysiological response curves obtained from experiments involving repeated measures. - Ecology 71: 1389-1400.

Pulliainen, E. 1965: Studies on the partridge in Finland. - Annales Academiae Scientiarum Fennicae A IV 93: 1-76.

Pulliainen, E. 1984: Peltopyyn suoliston koosta ja ravinnon kemiallisesta koostumuksesta. (In Finnish with English summary: On the gut size and chemical composition of the food of the Partridge (Perdix perdix) in Finland). - Suomen Riista 31: 13-18.

Putaala, A. & Hissa, R. 1993: Luonnonvaraisten ja istutettujen peltopyiden kuolleisuus ja lisääntymismenestys - radiotelemetrinen vertailututkimus. (In Finnish with English summary: Mortality and reproduction of wild and hand-reared grey partridge in Tyrnävä, Finland). - Suomen Riista 39: 41-52.

Putaala, A. & Hissa, R. 1995: Effects of hand-rearing on physiology and anatomy in the grey partridge. - Wildlife Biology 1: 27-31.

Putaala, A., Turtola, A. & Hissa, R. in press: Mortality of wild and released grey partridges in Finland. - Gibier Faune Sauvage 15.

Redig, P.T. 1989: The avian caeca: obligate combustion chambers or facultative afterburners? - The conditioning influence of diet. - Journal of Experimental Zoology, Supplement 3: 66-69.

Remington, T.E. 1989: Why do grouse have ceca? A test of the fibre digestion theory. - Journal of Experimental Zoology, Supplement 3: 87-94.

Robin, J-P., Cherel, Y., Girard, H., Géloen, A. & Le Maho, Y. 1987: Uric acid and urea in relation to protein catabolism in long-term fasting geese. - Journal of Comparative Physiology B 157: 491-499.

Savory, C.J. & Gentle, M.J. 1976a: Effects of dietary dilution with fibre on the food intake and gut dimensions of Japanese quail. - British Poultry Science 17: 561-570.

Savory, C.J. & Gentle, M.J. 1976b: Changes in food intake and gut size in Japanese quail in response to manipulation of dietary fibre content. - British Poultry Science 17: 571-580.

Servello, F.A. & Kirkpatrick, R.L. 1987: Regional variation in the nutritional ecology of ruffed grouse. - Journal of Wildlife Management 51: 749-770.

Siivonen, L. 1957: Peltopyy- ja rusakkokantojen vaihteluista ja niiden perussyistä sekä katojen torjumisesta. - Suomen Riista 11: 7-28. (In Finnish).

Starck, J.M. & Kloss, E. 1995: Structural responses of Japanese quail intestine to different diets. - Deutsche tierärztliche Wochenschrift 102: 146-150.

Suomalainen, H. & Arhimo, E. 1945: On the microbial decomposition of cellulose by wild gallinaceous birds (family Tetraonidae). - Ornis Fennica 22: 21-23.

Thomas, V.G. 1987: Nutritional, morphological, and behavioural considerations for rearing birds for release. - Journal für Ornithologie 128: 423-430.

Thompson, D.C. & Boag, D.A. 1975: Role of the caeca in Japanese Quail energetics. - Canadian Journal of Zoology 53: 166-170.

van der Meer, J. & Piersma, T. 1994: Physiologically inspired regression models for estimating and predicting nutrient stores and their composition in birds. - Physiological Zoology 67: 305-329.